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United States Overview

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SEQUENCING BATCH REACTORS: U.S. OVERVIEW

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16. ABSTRACT

The Sequencing Batch Reactor is a fill-and-draw activated sludge system. Each tank in the SBR system is filled with wastewater during a discrete period of time and then operated in a batch treatment mode. After treatment, the mixed liquor is allowed to settle for a predetermined amount of time and then the clarified supernatant is withdrawn from the tank. During treatment, sedimentation, and withdrawal the wastewater flow is either directed to another SBR tank in the system, as in a multiple tank configuration, or to a storage tank configuration where it is drawn for treatment after the supernatant withdrawal has been completed.

One modification of the SBR process, the intermittent cycle extended aeration system (ICEAS), operates on the principle of continuous feed as in a continuous-flow activated sludge system, but with intermittent withdrawal as in the SBR system. With the exception, therefore, of the ICEAS, an SBR system is comprised of either a storage tank and an SBR tank or a minimum of two SBR tanks to accommodate a continuous inflow of wastewater to the treatment plant.

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Figure 1 shows a single tank in each of the five periods of one complete cycle. The figure also shows the percent of the maximum liquid volume and total cycle time that is typical for each period and the purpose of each period. ICEAS has continuous fill, so it has no separate fill and no idle periods. The tanks in an ICEAS always have a prereaction compartment at the influent end terminating in a baffle that is designed to minimize disturbance during settle and draw. Other SBR systems may not have this separate prereaction compartment.

Historical Perspective

SBR technology is not new. In fact, it preceded the use of continuous flow activated sludge technology. There are many examples of batch processes in the history of municipal wastewater treatment. Many difficulties were associated with operating these fill-and-draw systems, most resulting from the process valving required to switch flow from one tank to the other and operator attention required in initiating different periods required in these batch systems. As a result of this, batch systems never became popular in large-scale municipal treatment plants. By 1920, when larger facilities were being constructed, batch systems were no longer considered viable. The birth and widespread use of continuous-flow systems resulted primarily from operational considerations and not from any process-related weakensses of the batch systems.

New hardware devices, such as motorized valves, pneumatically actuated valves, level sensors, flowmeters, automatic timers, and microprocessors or process controllers have been developed and have prompted reevaluation of what is now known as Sequencing Batch Reactors (SBR's).

The advantages of the SBR have been cited to include:

- An SBR tank serves as an equalization basin during fill and therefore can easily tolerate peak flows and shock loads of biochemical oxygen demand (BOD) without degradation in effluent quality.
- During the early design life, when flow is significantly lower than design capacity, liquid level sensors can be set at a lower level, so that a fraction of the SBR tank capacity is used. In this way, the length of treatment cycles can be kept the same as design without wasting power unnecessarily by over-aeration.
- No return activated sludge pumping is required because the mixed liquor is always in the reactor.
- Solid-liquid separation occurs under nearly ideal quiescent conditions. Short circuiting is nonexistent during the settle period.
- Filamentous growth can be easily controlled by varying the operating strategies during fill.
- An SBR can be operated to achieve nitrification, denitrification, or phosphorus removal without chemical addition.

Evaluation of SBR Facilities

A study was conducted which involved identifying operating SBR facilities through I/A coordinators of each state, equipment manufacturers, and representatives of Canadian provincial governments. The consulting engineers responsible for designing these facilities were also identified. The engineers were contacted to obtain important design information--design flow, BOD, and (where appropriate) National Pollutant Discharge Elimination System (NPDES) requirements. Based on a preliminary analysis of the information obtained and discussions with the EPA, all four SBR facilities operating in the U.S. were selected for post-construction evaluation. Two facilities in Canada and two facilities in Australia were also selected.

Discussion

The information amassed through a review of design documents and field trips was carefully analyzed. Several comparisons and conclusions were drawn:

- Operating staff at each of these plants indicated that the SBR process was more simple to operate compared to the conventional continuous-flow processes that they had previously operated.
- All plants were meeting effluent requirements with one exception, that of the ICEAS-type. The problem was alleged to be the result of an unsatisfactory decanter design, and the city is in the process of replacing the decanter.

- Even though the water quality objectives at the eight plants visited were essentially the same, the design criteria and the reactor sizes and power usages were not. For example, the theoretical detention time (V/Q) varied from 7.6 hours to 49 hours. The differences in the values of F/M ratio were also of the same order of magnitude as the detention time, 0.18 day^{-1} to 0.032 day^{-1}.

- The approach used by the design engineers in designing these plants varied from an entirely empirical approach involving sizing of the SBR reactor(s) based on somewhat arbitrarily selected detention times to an approach where sizing of the reactor(s) and aeration equipment was based on the values of organic loading F/M ratio, sludge concentration at the end of the decant period, and durations of different periods comprising the overall cycle.

- Partial to nearly complete nitrification was achieved in almost all facilities visited although it was mandated at only two.

- One of the facilities is currently removing phosphorus biologically to levels less than 1 mg/L without any chemical addition.

- The operating cycles (fill, react, settle) used at the facilities were also significantly different. For example, the react period varied from 22 hours to about 1.5 hours.

- Because of the differences in the operating strategies, power usage at these plants was significantly different; from as low as 0.8k Wh/kg BOD applied to as high as 22.9 kWh/kg BOD applied.

- Several types of decanter mechanisms are used at these facilities. They range from an extremely simple system that consists of one fixed vertical open-ended submerged pipe to a mechanically retractable decanter. All facilities in the U.S. experienced some difficulties operating their decanter mechanisms because these permitted, at one time or another, the MLSS to enter the decanter mechanism piping during fill, react, and settle. These solids were discharged during decant and affected the effluent quality.

- Five of the eight plants used jet aeration in the SBR tanks, two used diffused air aeration, and one used floating aerators. There seemed to be a preference for jet aeration because it provides the flexibility to have unmixed and unaerated fill, mixed only fill, mixed and aerated fill, or any combination of these.

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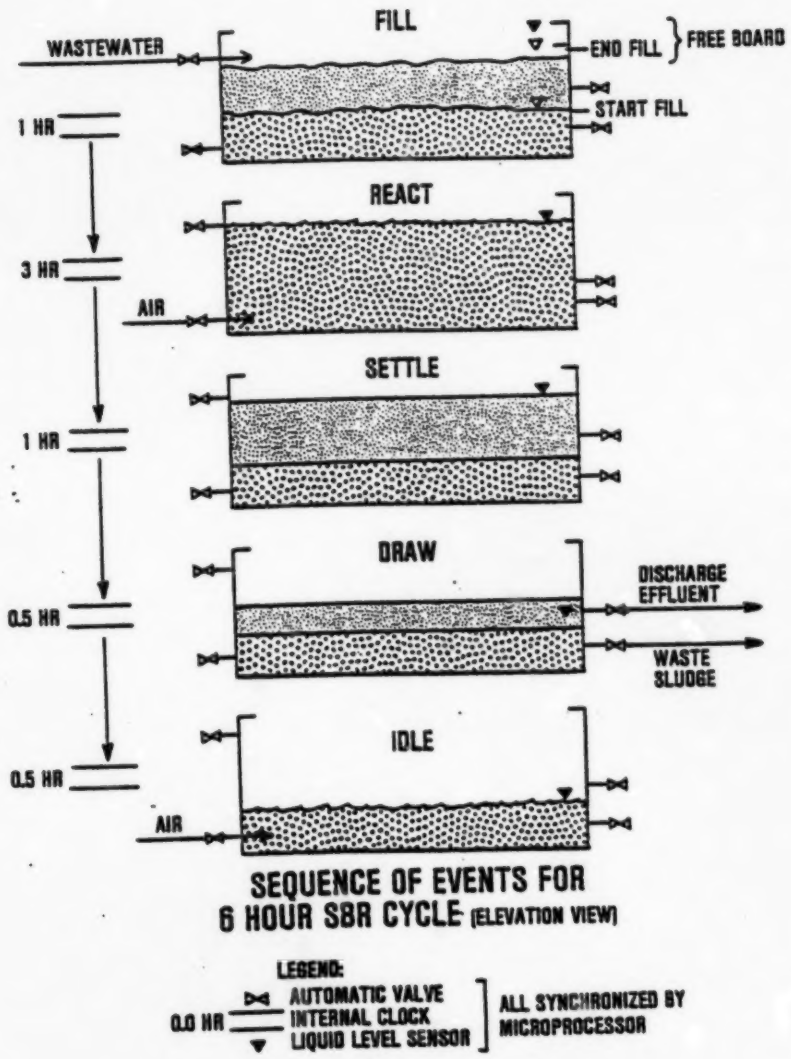

FIGURE 1. SEQUENCE OF EVENTS FOR 6 HR SBR CYCLE (ELEVATION VIEW)